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ORIGIN OF HETEROECISM IN THE RUSTS

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Since De Bary's classical demonstration of heteroecism in the rusts in 1864, there have been many speculations concerning the means by which this remarkable phenomenon could have arisen in an evolutionary way. In the case of tapeworms and other animal parasites in which a similar condition of obligate alternation of hosts obtains, it seems easier to work out in the imagination how such a change could have come about since a very evident food relation often exists between the two alternating hosts : as *e. g.*, between man and the pig, the cat and the mouse, the dog and the rabbit, etc. But when we come to examine the heteroecious rusts, we do not see any evident relationship between the two sets of host plants ; the one does not in the least suggest the other. It is true that, as von Tavel (1893) first pointed out, the alternate hosts of rusts are often members of the same plant societies ; but we note, on the other hand, that the two hosts seem only remotely related phylogenetically to each other, being practically universally of very different systematic position.

These facts may be readily illustrated by the following examples. It is well known that most of the heteroecious species of Puccinia and Uromyces have a predilection for utilizing grass and sedge hosts for their teleutospore generation ; thus being assured of a wide distribution and of a firm substratum in which to winter. Of the one hundred and more species of heteroecious Puccinia enumerated in the lists of Klebahn (1904) and Arthur (1899–1910), it is interesting to note that about fifty-six are found to produce their teleutospores on various grasses ; while about forty form their winter spores on sedges. Out of the total of more than a hundred, there remain only about nine species of heteroecious Puccinia to seek teleutosporic hosts outside the Gramineae and Cyperaceae. One of these nine species bears its teleutospores on Luzula ; six of them utilize Polygonum for this purpose ; one goes to Impatiens ; and one to Prunus. An analysis of the fifteen species of heteroecious Uromyces in the lists of Arthur and Klebahn

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reveals conditions somewhat similar to that seen in the case of Puccinia. Six species bear their teleutospores on grasses; five species go to various sedges; while only four seek hosts outside the families of grasses and sedges. There is likewise absolute lack of any evident suggestion between the alternate host plants of these four species, since two of the latter are Juncus-Compositae combinations, while the other two form Leguminosae-Euphorbia combinations.

It will be further seen by an examination of the aecidial hosts of the grass and sedge rusts that there is an equal lack of suggestion of the one host by the other. Of the sixty odd species of Puccinia and Uromyces with teleutosporic stage on grasses, about fourteen go to various members of the Ranunculaceae for their aecidial stages; only about four to the Compositae. On the other hand, of the forty species of Puccinia on sedges, about twenty-five bear their aecidia on Composites, with none going to the Ranunculaceae. We note further as one of the most remarkable facts in our examination of these peculiar relationships of alternating hosts that of the ten forms of heteroecious Puccinia noted by Klebahn which bear their aecidia on three or four families of the Monocotyledons, seven go over to a single grass host, *Phalaris arundinacea*, to produce their teleutospores.

The main point toward which we wish to try to contribute in this paper, if only in a theoretical way, concerns the problem as to which of the two hosts (granting autoecism to be the original condition) is to be regarded as the primary, and which the secondary host. Is the barberry, for example, the primary host of *Puccinia graminis* and wheat the secondary; or were, on the other hand, the grasses the primary hosts, bearing all stages, the aecidium of which was later transferred to barberry? Such a question is admittedly a difficult one, since in the very nature of the case no one has ever been able to observe an autoecious fungus becoming heteroecious. The difficulty of the question is increasingly obvious when we reflect that the origin of heteroecism really is closely connected with the problem of the phylogeny of the group as a whole.

Fischer (1898) supposed the ancestral form of the present heteroecious species to have been autoecious but able to live on a large variety of hosts. Such an autoecious, plurivorous rust was supposed to be able to live its whole life history on either of the two present hosts, as well indeed as on a large number of other plants. Somehow, in a way difficult to imagine, the present condition of affairs was in recent times brought about, with the two generations of the fungus at last highly specialized, and attacking plants widely removed from each other in systematic relationship. For instance, Fischer imagined that

in the case of the present heteroecious "crown rust," the original form lived on both the grasses and Rhamnus as an autoecious fungus and that it could undergo its whole development on either of these diverse hosts. In partial support of Fischer's view an Argentine rust is sometimes cited—*Puccinia graminella* (Speg.) Dietel & Holway—which has both aecidia and teleutospores on the same grass host, Stipa. But there are no indications whatever of this form having any plurivorous habit since, so far as is known, it does not depart from its one host but is confined in its complete development to Stipa. Fischer's theory has, moreover, been vigorously assailed by both Magnus (1899) and by Klebahn (1904). Klebahn points out that the chief argument against Fischer's view is the fact that there is no present analogy among rust fungi of a long-cycled species like a eu-form, *e. g.*, being able to carry on complete development on either one of two sets of hosts so widely different as Rhamnus and the grasses, or the Barberry and the wheat.

Dietel (1899, 1902) has contributed perhaps the most reasonable theory along these lines. He thinks that the ancestral forms of heteroecious rusts were the short-cycled lepto- and micro-forms. The following example illustrates his theory. The lepto rust, *Puccinia mesnieriana* Thuem, produces the one spore-form—a teleutospore crowned with finger-like processes—on several species of Rhamnus. According to Dietel, this species may be regarded as similar to the hypothetical autoecious "crown-rust" ancestor of the present Rhamnus—grass combination, seen in *Puccinia coronata* and *P. coronifera*. When such an ancestral form began at last to extend its vegetative period and to produce aecidia and eventually uredospores, it somehow lost the power of completing its development on the original Rhamnus host, and the teleutospore-uredospore generation was consequently transferred to new hosts among the grasses. Magnus (1898) and MacAlpine (1906) hold essentially the same ideas in regard to the origin of heteroecism.

Christman (1907) also accepts Dietel's view; arguing the matter, however, mainly from a cytological standpoint. Since, as Christman points out, general analogous considerations in the case of algae and and higher plants compels us to believe that the gametophyte generation should be regarded as the primitive generation, it follows logically that those forms with shortest sporophyte, *i. e.*, the lepto- and micro-forms, must be held as nearest like the primitive ancestral rusts. Or, perhaps we may regard, with Barclay (1891), forms like the more complex Endophyllum, in which the teleutospores are borne in chains and enclosed in a cup, as the ancestral type. But it appears much

more reasonable to regard the aecidium-like teleutospore-cup in the latter instance as a secondarily derived structure, and to hold as the more primitive conditions those in which an indefinite number of sexual fusions occur at the base of a simple sorus of teleutospores, such as I assume we have in the present lepto- and micro-forms.

According to Christman's view, as the cell-fusions are pushed back farther and farther from the teleutospore, and the sporophytic generation consequently becomes longer and longer, an aecium stage with a new form of binucleated spore is finally intercalated between the cell fusions and the final teleutospores. At first, the aecium stage is a primary uredo, in which the spores, borne on long stalks, are formed singly by repeated budding from large fusion cells, often followed, after repeated uredospore infections, by successive crops of similar, though secondary, repeating spores. Next, instead of singly as in the primary uredo-form, the spores now remain fastened in chains, with small rudimentary stalk cells between them, thus forming the so-called caeoma rusts. Finally, as the culmination of sporophytic complexity in the group, comes the eu-type of rust, having spores borne like those of the Caeoma, in chains, but enclosed in definite cup-shaped groups, each of which is surrounded and protected by a peridium ; these aecidiospores followed in turn either by the similar secondary aecidiospores or by the heteromorphic repeating spores, the so-called uredospores ; and, finally, by the constantly present teleutospores. According to Christman's idea, the heteroecious eu-forms thus represent the latest type in evolutionary history of the rusts, and the highest in complexity.

It certainly seems highly illogical, to say the least, to hold the opposite view, as do Blackman (1904, p. 361) and others, who regard the complicated eu-forms and even heteroecism itself as the primitive condition and the simpler micro- and lepto-forms as arising latest in evolution in an apogamous way by process of degeneration and elimination of spore forms. From analogy, derived from our present interpretation of the evolution of higher plants, it seems to me that we are justified rather in accepting Christman's view, in which those rusts with longest sporophytic stages, *i, e.*, the eu-forms, are regarded as having arisen in a progressive way, and not to be looked upon as the complicated type from which by retrogression and elimination are obtained the more simple -opsis, brachy-, lepto- and micro- forms.

Accepting, then, for the present, the view that the heteroecious eu-forms were the last in evolutionary history, and that the earliest ancestral stock consisted of forms which were in all probability similar to the present lepto- and micro-rusts, we come back to the original

question as to how the jump to a new host could have come about; which was the primary host and which the secondary?

Assuming, as we must, that the teleutospores were the original and oldest of the sporophytic spore-forms, then we might strongly argue from this assumption that the present teleutosporic host must have been the original host—the grass hosts for *Puccinia graminis*, for example, and the Juniper for Gymnosporangium. But from a cytological standpoint it seems inconceivable that the jump to foreign protoplasm could have been made by the uninucleated basidiospores resulting from the germination of the teleutospores; since this profound change would be thus made at a time when the reduction divisions occur which change the fungus from the presumably more vigorous double-nucleated generation back to the more primitive uni-nucleated, or gametophytic, generation.

Of the two perhaps most critical stages in the ontogeny of the rusts; the stages of the sexual cell fusions and reduction, the former gives undoubtedly the greatest increase in life energy and the greatest stimulus to growth. This conclusion follows from the fact of the very marked stimulation to growth which results from the sexual fusions. Sometimes, it is true, the gametophyte may seem to live on more or less indefinitely, permeating the entire host, as in the case of the rusts on Callirrhoe, Euphorbia and others (Carlton, 1904; Klebahn 1904, p. 54 f.); but generally the growth of gametophytic mycelium is quite limited. In both limited and unlimited growth of the gametophytic mycelium, however, the sexual fusions undoubtedly impart the stimulus necessary for aecidiospore production. A case in point was observed in my preparations in which in certain old sterile aecidium cups no fusions had apparently taken place and consequently no spores had been formed. The uninucleated cells of the sorus appeared, however, to be able to continue growth for a time; but the resulting pustule did not in any case sufficiently develop to break through the epidermis. On the other hand, if the sexual fusions took place in the normal manner at the base of the aecidium cup, a rapid growth at once ensued, multinucleated cells being first formed in many instances, and in all cases numerous, vigorous, binucleate spores finally result, which rupture the epidermis and scatter to the winds. Further, the exceptional vigor of aecidiospore infection is well known, especially in the case of wheat rust, this method, according to Plowright, Arthur, Bolley and others, resulting in a decidedly more vigorous infection than that which comes from uredospore infection.

It should be here noted that these facts, although seemingly having a direct bearing on the problem of rejuvenescence, are in reality only

indirectly concerned with it. The rejuvenescence of an organism, as ordinarily understood, applies to the stimulation of a mature organism suffering from depressed vitality, or from old age. Viewed in this sense, the observations on the rusts noted above have really no bearing. Rather are these observations to be interpreted as of the nature of the stimulation of an egg to further growth. It is true that gametic differentiation and sexual fusions in the gametophytic mycelium may be deferred under certain conditions, as noted above, and the gametophyte may consequently continue for a time its development, though showing reduced growth. But it is regarded as proven for the rusts that the stimulus of sexual fusions is ultimately necessary for changing over the uninucleate gametophyte into the binucleate sporophyte and for the formation of the binucleate spores capable of continuing the development of the parasite. The main point under contention is, therefore, whether the stage of the sexual fusions furnishes a greater amount of stimulation and a greater degree of vigor than any other stage in the ontogeny of the rusts. This is really comparable to the general query, as to whether fertilization of the egg furnishes the greatest amount of life energy in the life history of the individual. I believe this to be true for the rusts.

A careful perusal of the facts leads inevitably to the conclusion that the stage of the sexual fusions is in reality as necessary a step and fully as important morphologically as the final stage of teleutospore formation ; as well indeed as the most invigorating phase of the whole life history. While it is undoubtedly true, as was mentioned above, that the teleutospores must be regarded as the only spore form of the ancestral rusts ; yet it must be equally true that the earlier sexual fusions which I assume invariably precede the teleutospores constitute a stage which also must have existed from the very beginning of the developmental history. The fusion cells are as truly morphological units as are the teleutospores. Indeed, a careful examination of certain points in the life history of the rusts, viewed mainly from a cytological standpoint, leads us to the belief that that host in which the sexual fusions occur, *i. e.*, the present gametophytic host, is to be regarded as the original host of the hypothetical autoecious ancestor of the present day heteroecious rust. These arguments are as follows: first, since the uninucleate gametophytic stage of the rust, which extends from the basidiospores to the sexual unions, is from analogy to be regarded as the primitive generation, it follows that the present gametophytic host probably served as host of the primitive autoecious ancestor. Second, it seems quite probable that the uninucleate basidiospores could not make the jump to a new host as readily as

could the more vigorous binucleate aecidiospores; therefore the original host was quite likely the present aecidiosporic host and *not* the present teleutosporic host. It would certainly seem more reasonable to expect, that the diploid aecidiospores, endowed with the greatest amount of vitality from the conjugation which has just preceded them, would be thus much better adapted to make the wide jump to another distinct host than the just reduced, haploid basidiospores. We should naturally expect that new possibilities of development and consequently new possibilities for infection of foreign protoplasm, might sometimes arise possibly by mutation, after the subtle changes induced in the young sporophyte by the invigorating sexual fusions; rather than that the first-formed spores of the primitive gametophyte, the basidiospores, should show such profound modifications and possibilities.

The fact that the aecidiospores are able, in some heteroecious species, to act as a bridge for the transfer of the sporophytic generation from one host to another closely related, even when it is impossible to make this change directly by means of the uredospores, argues conclusively for the greater vigor and greater infecting power of the aecidispores over other forms of rust spores.

All heteroecious rusts would be thus regarded, according to this theory, as starting their existence as autoecious fungi on the present gametophytic host. The barberry, for example, would be looked upon as the primary host of *Puccinia graminis*: the apple and other related Rosaceae would be, according to this view, the original hosts of Gymnosporangium and the Juniper secondary.

It is axiomatic that the change from the primary to the secondary host must have been accomplished either by the aecidiospores or by the basidiospores. There is no other possibility. The loose statement is therefore incorrect to say that the uredospores or the teleutospores jump to another host; the vigorous aecidiospores really make the jump and the uredospores and the teleutospores develop in the new host from the mycelium which comes from the aecidiospore infection. It is true that in the case of certain cereal rusts, the uredospores undoubtedly have the power of producing infection in certain near relatives of the host which bears them; but this phenomenon is by no means comparable to the wide jump of the aecidiospore from the primary host to a secondary one, as from the barberry to the wheat; or from the Rosaceous hosts to the Junipers.

To my mind the main argument in favor of the theory that in the origin of heteroecious conditions, the primary host that bore the hypothetical autoecious ancestor must have been the present aecidial

host, in which the sexual fertilizations occur, is based on the cytological considerations mentioned above. Aside from this a strong point in its favor is seen in forms with pleophagous sporophytes, such as possessed by *Puccinia graminis*. Here we have, at least so far as the morphological species is concerned, a case in which a few species of barberry act as the hosts of the gametophyte, and a large number of species of grasses as the hosts of the sporophyte. Because of the very close morphological resemblance of the several biological forms of *Puccinia graminis*, we may argue with Klebahn that all of these forms must have had a common origin, probably from a plastic form like that on wheat, and that through time and gradual adaptation to the different substrata presented by the various sorts of grasses chosen as host plants by the sporophytic generation, have taken on somewhat different physiological peculiarities. The fewness and evident close relationship of the gametophytic hosts argues strongly that the barberry was the original host in this case and that the vigorous aecidiospores were able in their wide jump from the barberry over to a secondary host to infect many sorts of grasses, thus indicating that a plurivorous tendency had been imparted to the aecidiospores by the sexual conjugations. Bolley (1906), for example, was able to infect seven different grass hosts from a single barberry hedge. A still further argument in favor of this theory is furnished in the fact that several species of barberry in various parts of the world act as hosts for the teleutospores of several species of autoecious Puccinias (Sydow 1904, p. 521 f.); thus suggesting the possibility that at one time the barberry, besides furnishing a substratum for the stage of the sexual fusions, as it does now for the heteroecious *Puccinia graminis*, may have served also at one time as ancestral host to the teleutospores of this same species.

The remarkable pleophagous character of the sporophytic stage of *Cronartium asclepiadeum* (Willd.) Fr. likewise affords a strong point in favor of this hypothesis. This species attacks in its teleutosporic stage, hosts in four families of flowering plants, Asclepiadaceae, Ranunculaceae, Scrophulariaceae and Verbenaceae; while its aecidial stage is passed solely on *Pinus sylvestris*. It seems quite reasonable to suppose that this pleophagous habit of the sporophytic generation may have come about from the invigorating influence imparted to the aecidiospores by the sexual fusions which took place in the ancestral host—the pine.

It is indeed significant that we should find so abundantly this phenomenon, in which the sporophytic generation is able to attack any one of several, sometimes even remotely related host plants; while the

gametophytic stage of these same species remains closely confined to the one species of host.

Besides the two illustrations just given to show the pleophagous tendency in the sporophytic generation, several other examples of heteroecious rusts may be cited which show clearly this phenomenon, though to a somewhat lesser degree. *Melampsorella caryophyllacearum* (DC.) Schroet., for example, with its gametophytic stage on Abies, attacks in its sporophytic stage nine or ten species, in five distinct genera of the Caryophyllaceae. *Puccinia caricis* (Schum.) Rebent. with aecidium on Urtica, shows the plurivorous character of its sporophytic generation by attacking at least ten species of Carex. *Puccinia coronata* Corda, infecting Frangula in the spring stage, later attacks seven genera of grasses; *P. coronifera* Kleb. with early stage on Rhamnus, goes over in its diploid generation to six or seven genera of grasses; and finally, *Uromyces Pisi* (Pers.) De Bary, with aecidium on Euphorbia, produces its teleutospores later in three genera of Legumes—Pisum, Lathyrus and Vicia.

On the other hand, an apparent point against this theory is furnished by such a remarkable and exceptional form as *Puccinia subnitens* Diet., in which the gametophytic generation appears to show the pleophagous habit, and not the sporophyte. As Arthur (1909) has shown, *Puccinia subnitens* produces its aecidia on various species in three families—Cruciferae, Capparidaceae and Chenopodiaceae, whereas the teleutospore generation goes to one grass host, *Distichlis spicata*. Of course we may readily believe that the Cruciferae and the Capparidaceae are closely related systematically to each other; but the Chenopodiaceae are, so far as we can judge from external characters, remote in systematic relationship from the first two families. We must apparently conclude in this case that the basidiospores show an unusual power of choice in their jump back to the gametophytic host.

Although such a phenomenon is rare, we may trace similar conditions in two species of Gymnosporangium. *G. clavariaeforme* (Jacq.) Reess., for example, attacks eight species in three genera of Rosaceae in its gametophytic stage; while *G. globosum* Farl. also has considerable power of choice in its basidiospore infection, since it may attack in this stage any one of five or six species, distributed in three genera of Rosaceae.

To briefly summarize: that theory of the phylogenetic origin of the rusts appears the most reasonable which derives the more complex types ultimately from the simpler lepto- and micro-forms by progressive development of the sporophyte. This conclusion follows logically from analogy with higher plants.

Further, the theory is held that in the origin of heteroecious conditions, the host which bore the hypothetical autoecious ancestor was the present gametophytic host. This conclusion is based on several facts and cytological considerations. First, since the uninucleate gametophyte is undoubtedly the more primitive condition of the fungus, it follows that the primary host of the autoecious ancestor was quite likely the present host of this gametophyte and the present sporophytic host was secondary. The stage of the sexual fusions marks the origin of the binucleate sporophyte; and it is argued that this stage has equal morphological value with the teleutospores. The only two necessary stages, in fact, in the ontogeny of the rusts are those of the sexual fusions and teleutospore formation. All other structures of the rusts are regarded as secondarily acquired.

Second, it is held that the stimulus imparted by the sexual fusions, being of the nature of the stimulation of an egg, is the most profound and the most invigorating of the whole life history. It therefore follows that the diploid aecidiospores, which are produced shortly following these fusions, are endowed with more vigor than any of the rest of the forms of rust spores; and are thus the most capable of infecting foreign protoplasm. We may therefore argue that, in the origin of heteroecism, the original jump to secondary host plants must have been performed by the vigorous aecidiospores, and not by the uninucleate basidiospores. The possibility of bridging by means of aecidiospores argues further for their vigor.

Finally, the prevalence of heteroecious forms with pleophagous sporophytes is regarded as a strong argument in favor of the theory that the pleophagous habit arose directly from the invigorating influence of the sexual fusions. The fewness and evident close relationship of the gametophytic hosts in each of these cases; as well as the multiplicity and remote relationship of the sporophytic hosts argues that the present gametophytic hosts were the primary hosts of the hypothetical autoecious ancestor.

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THE WINTERING OF PUCCINIA GRAMINIS TRITICI E. & H. AND THE INFECTION OF WHEAT THRU THE SEED

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(WITH PLATE XXII AND TWO TEXT FIGURES)

It was shown by the writer in a former paper[1] that *Puccinia graminis tritici* E. & H. lives over winter in certain wheat grains and thus probably causes direct infection of the young plants. To obtain further evidence upon this point wheat seedlings have since been grown from rusted grains, sectioned by means of a microtome and studied microscopically.

Wheat grains were selected for growing seedlings by the appearance of the hilum. When the grains are badly infected one pustule of teleutospores frequently lies in this area, the spores extending outward giving it a black color. All grains with any pronounced discoloration surrounding the hilum were avoided as during germination they are often covered with mycelium and spores of Alternaria or Helminthosporium.

The infected seed was planted in pots filled with garden soil and set in the ground while it was still frozen early in the spring at Washington, D. C. On account of the cold, the plants grew very slowly. When they had attained a height of four to ten inches they were carefully removed from the soil without detaching the seed grains, washed in water, killed in Flemming's strong fixing solution and imbedded in paraffin.

Further study of the material was made in the laboratory of Dr. E. W. Olive at Brookings, South Dakota.

The best results in staining were obtained by the use of safranin, gentian violet and orange G. Iron haematoxylin was also used but it failed to stain the nuclei as sharply as the triple stain and had a greater affinity for the metachromatic granules which were abundant in the cytoplasm and when arranged in groups were sometimes difficult to distinguish from nuclei.

INVESTIGATION

In order to reduce the amount of cutting, staining, etc., to the minimum, the wheat grains first selected were re-examined by means

[1] A Preliminary Report on the Yearly Origin and Dissemination of Puccinia graminis in North Dakota. Botanical Gazette, **42**: 169. Sept., 1911. This paper contains a review of the pertinent literature.

of a hand lens and only those in which a teleutosorus was definitely visible were retained for growing seedlings. Often the teleutospores break thru the surface of the hilum only around its margin forming a more or less broken ring as shown in text figure 1, but if the hilum is moistened and scraped lightly other teleutospores may usually be seen.

The fungus is not confined to the hilum, however, but deeply invades the pericarp and spreads out in various directions. Large masses of mycelium are present and one or many spore beds are formed. One pustule of teleutospores frequently presses against the embryo and as many as eight distinct pustules have been seen in a single section of a grain of durum wheat. Generally all pustules except the one covering the hilum are formed within the pericarp and the teleutospores are usually pointed inward towards the embryo or towards the endosperm.

Figure 1. Three grains of Blue Stem wheat showing teleutospores in the margin of the hilum.

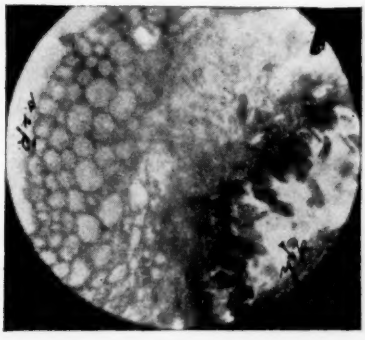

Figure 2. Portion of a section made from a grain of Blue Stem wheat four weeks after germination showing part of an internal pustule of teleutospores imbedded in the pericarp and the relative position of the young plant. The outer edge of the pericarp is shown at *o. e. p.* a few cells of the plant at *y. p.*

Figure 2 shows part of an average internal pustule. The section was taken from a grain of Blue Stem wheat four to five weeks after germination. The outer edge of the pericarp is shown at *o. e. p.* and the position of the young plant at *y. p.* Pustules, however, which form a depression in the embryo give a far more striking appearance.

The teleutospores showed definite signs of activity, but no cell divisions or palmella stages were found as previously described.[1]

At the base of the spore pustules living filaments of rust were mingled with seemingly empty hyphae. Two short pieces of typical mycelium seen in this region are shown in plate XXII figures 1 and 2.

A considerable rust mycelium was even found in the root of the young plant. Figures 3 and 4 represent typical pieces lying respectively in the central cylinder and epidermis of the root.

The fungus was found in abundance also in the young stem. It fills the intercellular spaces but freely invades the cells as well. Sometimes three and four hyphae crowd into a single intercellular space enlarging and distorting it but as a rule only one or two filaments are present. Such appearances are shown in figures 11 and 14 *a*, *b* and *c*. Figure 14 also shows intracellular hyphae, the majority of which are cut transversely. Where a filament passes through the protoplasm of a host cell it is often surrounded by a clear space which is apparently a digestion vacuole. Such phenomena are shown in figure 14. Figures 9-10 and 12-13 represent cells of the mycelium lying in the host cells of the stem.

One of the most interesting observations was the presence of mycelium between the leaf sheaths. Only about one-half inch of the base of each plant was sectioned but in the narrow space between the sheaths one or more long filaments of rust were commonly found which sent branches into the tissues here and there but continued to grow along the cavity. Figures 6, 7 and 8 show single pieces of such hyphae. Sometimes several long filaments lay side by side. In figure 5, the first or outer leaf sheath is shown at *a* and the second or adjacent sheath at *b*. The rust filaments lie chiefly in the intervening space at *c* but they have also entered the cells of the second sheath. The nuclei are not very distinct as this preparation was poorly stained.

CONCLUSIONS

The mycelium observed in the pericarp of wheat grains and in various parts of wheat seedlings stained and looked alike and appears to be the same fungus. Moreover it closely resembles the mycelium of *P. graminis* and other Uredineae and the cells are prevailingly binucleate, which is characteristic of rusts and in fact of Basidiomycetes in general. See especially figures 2, 4, 6, 7, 10 and 14.

In order to ascertain whether infected wheat grains are sufficiently abundant in what are commonly known as non-rust years to carry

[1] Loc. cit.

Puccinia graminis thru dry seasons the writer visited the elevators at Brookings and obtained samples of wheat from last year's crop which was grown in a dry year comparatively free from rust. Infected seeds were found in all samples examined and they were even abundant in some varieties, especially in Blue Stem.

At least one source of spring infections of wheat by *Puccinia graminis* is plainly evident for the fungus lives over winter in certain wheat grains and infects the young plants. The mycelium from the pericarp penetrates various parts of the seedling invading both the intercellular spaces and the cells. It soon passes into the spaces between the leaf sheaths where it grows rapidly and attacks the tissues at various points. This peculiar mode of travel and attack may explain the failure of Eriksson and Ward to trace the fungus filaments beyond the immediate confines of the first-appearing pustules, for these areas of infection may not spread while being carried up by the growth of the plant.

The relative number of wheat plants bearing early uredo pustules of *Puccinia graminis* will vary with the proportion of infected seed planted. As a rule only scattered plants show this early infection and the general spread from plant to plant in this northwestern region depends largely upon the conditions of the weather in July and August and has no particular relation to the weather in the spring as formerly supposed.

The weather was extremely dry in South Dakota this spring and especially around Brookings. No aecidia, as far as careful examination has revealed, appeared upon the barberry and by the 26th of June no uredo pustules were observed upon the grasses altho at this date the uredo stage of *Puccinia graminis* was fairly abundant upon the wheat. This occurrence quite agrees with observations made formerly at Fargo, North Dakota, where *Puccinia graminis* appeared upon the wheat earlier than upon the grasses.

The obvious remedy for avoiding the ravages of this fungus and overcoming epidemics of black rust is the use of clean seed. It is quite evident that only seed from a crop free from rust should be planted.

Experiments should certainly be made with Jensen's hot water treatment of the seed after a previous soaking in cold water to stimulate the growth of the fungus but the use of chemicals is practically beyond the pale of consideration as the fungus is often much better protected by the pericarp coverings than is the embryo itself.

In conclusion the writer wishes to acknowledge his indebtedness to Dr. E. M. Freeman, Dr. Howard S. Reed and Miss V. W. Pool for

furnishing rusted wheat seed, to Miss Ethel C. Field for aid in preparing material and especially to Dr. E. W. Olive for consultation and suggestions.

BUREAU PL. IND., U S. DEPT. AGR.,
WASHINGTON, D. C.

EXPLANATION OF PLATE XXII

All the drawings were made on a level with the table by means of a camera lucida, a Zeiss 2 mm apochromatic objective and a No. 6 ocular and reduced one-third when reproduced.

1–2. Typical pieces of mycelium lying at the base of teleuto pustules imbedded in the pericarp.

3. Mycelium from the central cylinder of a young root.

4. A portion of mycelium from the epidermis of a root.

5. Mycelium growing in the space between the leaf sheaths and also invading the cells of the second sheath.

6–8. Typical pieces of mycelium growing in the space between the leaf sheaths.

9–10. Cells of the mycelium lying in the stem.

11. A cross section of filaments growing in the intercellular spaces of the stem.

12–13. Representative cells of the mycelium found in the stem.

14. A portion of the stem showing the presence of rust hyphae both in the cells and intercellular spaces and also digestion vacuoles.

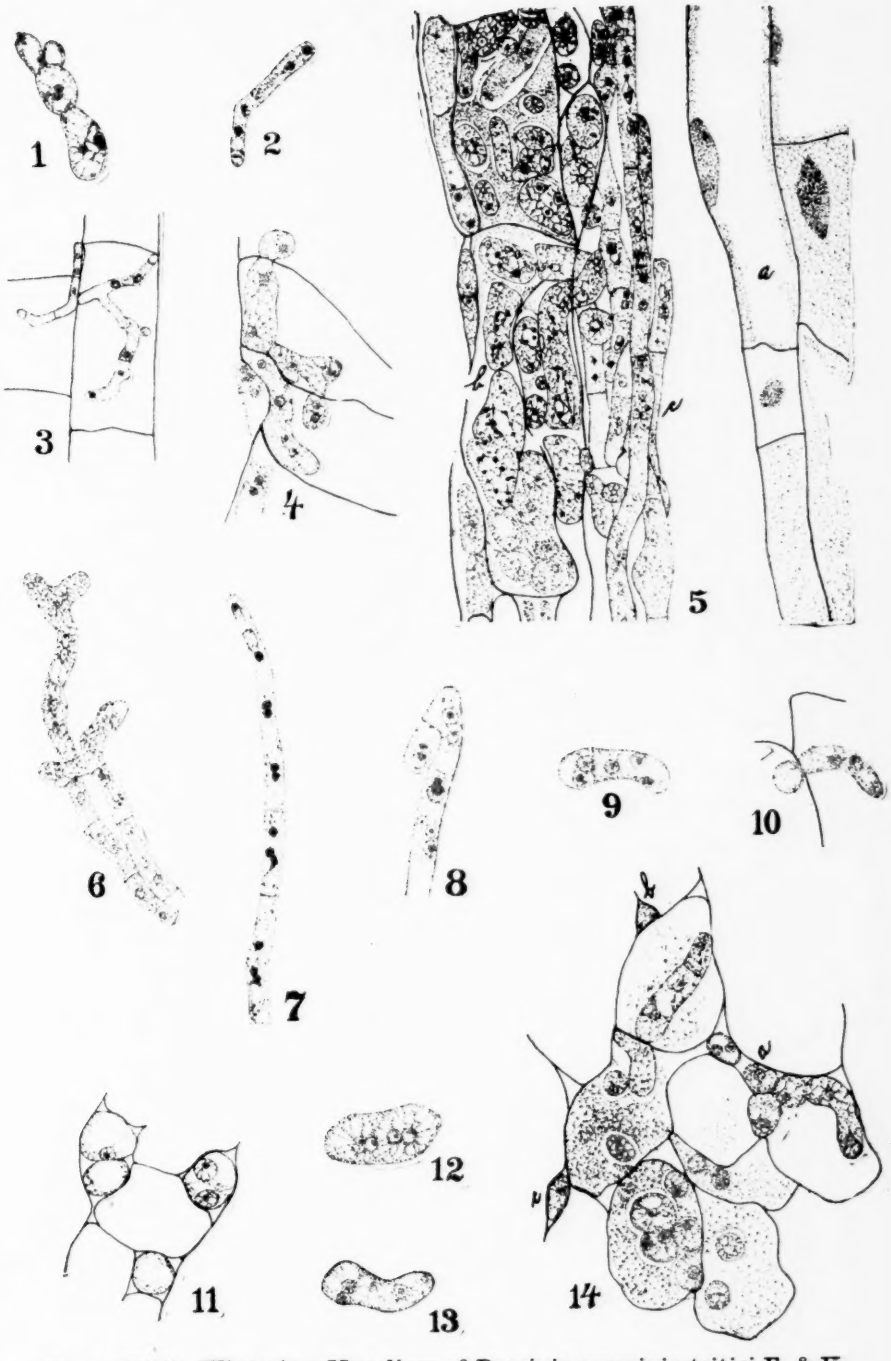

PLATE XXII **Wintering Mycelium of Puccinia graminis tritici E. & H.**

SCOLYTUS RUGULOSUS AS AN AGENT IN THE SPREAD OF BACTERIAL BLIGHT IN PEAR TREES

DAN H. JONES

(WITH PLATES XXIII AND XXIV.)

In Bulletin 176 of the Ontario Agricultural College—"Bacterial Blight of Apple, Pear and Quince Trees"—we stated that we had traced a number of pear tree infections of Bacterial Blight to inoculations made by *Scolytus rugulosus*. A detailed and illustrated account of our observations is there given which is summarized as follows: "The facts, so far ascertained, regarding *Scolytus rugulosus* as a means of spreading the Bacterial Blight in pear orchards are:

1. This beetle has been found within and beneath the bark of both diseased and healthy trees.

2. Beetles caught issuing from their burrows in blighted trees have shown the presence upon their bodies of immense numbers of blight organisms when they were allowed to walk over the surface of gelatin and agar plates.

3. Beetles have been found in what was to all appearance, sound, healthy, vigorous pear bark before their entrance, but which has developed a limited though spreading blighted area in the immediate vicinity of their boring.

We conclude, therefore, that *Scolytus rugulosus* is one means of spreading the blight in pear trees.

The above statements have been substantiated to a remarkable degree by our subsequent observations.

In the spring of 1910, in an orchard under observation, some pear trees affected with the blight and infested with *Scolytus rugulosus* were cut down but not removed or destroyed until some weeks later. In the meantime two rows of young pear trees were planted alongside where these diseased trees had been growing. These young trees were free from all signs of any disease or insect injury when planted, and care was taken not to injure them in the planting.

Towards the latter part of June it was noticed that some of these trees did not look as vigorous and healthy as they should. The leaves were light colored, somewhat flaccid, and had a tendency to droop. In some cases bunches of blackened leaves typical of blight were present. On close examination trees so affected were found to be suffering from Bacterial Blight canker, with fresh active lesions spreading in various parts of the trunk and limbs. *Further, it was found that every lesion had within it a boring of Scolytus rugulosus*, and

the beetles could be seen passing in and out of the borings and passing to other parts of the tree and making new borings.

During the summer the orchard was cultivated but nothing was done to the trees to check the spread of the disease or to control the beetles. As a result, by the end of July, over sixty per cent of the trees planted out were suffering from the disease.

From careful examination we concluded that every inoculation had been made by *Scolytus rugulosus*, as a boring of this beetle was found somewhere near the centre of every lesion, no matter how old and large or how small and fresh the lesion was.

Some lesions were so large as to practically girdle the trunk or limb on which they occurred. Evidently it was these large lesions on the trunks of the trees that was responsible for the wilting of the leaves, the flow of sap being more or less interfered with. The largest cankers were usually on the trunk near the ground.

The beetle borings on the trunk were usually either within or immediately beneath a bud scar or limb, and those on the limbs almost invariably just beneath the axil of a leaf, fruit spur or branch, at the junction of these with the branch on which they grew. To be seen they had to be looked for closely. They were about a millimeter in diameter, circular and clear cut unless the orifice had been damaged, which was seldom the case.

The borings on one tree from the base of the trunk to the ends of the branches numbered two hundred and fifty-four. The great majority of these had typical blight cankers of various sizes spreading around them. Several of these were microscopically examined and plate cultures made and *B. amylovorus* was invariably found in large numbers. These cankers had so sapped the vitality of the tree that it was reduced to a dying condition by the middle of September.

An experiment with *Scolytus rugulosus* was conducted as follows: A virile, healthy, young tree was selected and three lengths of glass tubing of an inch and a quarter diameter after being sterilized were slipped over three of the young branches. The bottom end of these tubes was then stopped up with cotton. Several beetles were then obtained from a diseased tree by means of sterile forceps and test tubes and put into each of two of the the tubes, the third tube being left as a control. As soon as the beetles were put into the tubes they were seen to run up and down the branch for a minute or so, and then to settle down to boring operations, each one beneath a bud or leaf axil. Within an hour water of transpiration had condensed on the insides of the tubes to such an extent as to obscure the clear view of some of the beetles. By next morning several beetles that had got

into the drops of this water on the sides of the glass were drowned. After three days the tubes were removed for observations to be made, when it was found that five borings had been made in one branch and six borings in the other. The tubes were then returned for four days, after which blight cankers could be seen to be developing around a number of the borings, Fig. 5. Plate cultures in beef agar were made from one of these cankers and *B. amylovorus* isolated.

Of course unnatural conditions prevailed inside these tubes, as the water of transpiration could not pass away by evaporation. No signs of disease of any kind, however, developed in the control branch,

These observations, together with those stated in Bulletin 176, we consider prove most conclusively that *Scolytus rugulosus* is a very active agent in the spread of Bacterial Blight ("Fire Blight") among pear trees.

This being the case, steps should be taken in every pear orchard to destroy *Scolytus rugulosus*. One of the most effective means toward this end is to burn, during the winter or in early spring, all cut away or dead wood removed from the trees. This should never be neglected where such wood shows presence of the beetle by its borings. The eggs of the beetles are deposited within the tunnels which branch out in large numbers from the base of the external boring. The eggs usually hatch out in a few days and the larvae winter over in the tunnels, extending them very considerably and issuing in large swarms the following spring as adult beetles.

The trees shown in Fig. 1 were allowed to remain standing in the orchard until May of the present year. We examined them during April and found large numbers of larvae and dormant beetles present in every case. Figs. 8 and 9 represent the crotch of the tree shown in Fig. 6, as it appeared at the end of April. Notice the typical blight blistering and cracking of the bark in Fig. 8. The external borings cannot be easily distinguisned in the photograph but were readily visible in the tree. Fig. 9 gives the same view with the bark turned back to show the tunnelings of the beetle. Many larvae were present in these tunnels. All the trees were similarly affected.

ONTARIO AGRICULTURAL COLLEGE,
GUELPH

PLATE XXIII

FIG. 1. Young pear trees, of different varieties, killed by bacterial blight after being inoculated with *B. amylovorus* by *Scolytus rugulosus* in the spring and early summer of 1910. Photograph taken September 10th, 1910.

FIG. 2. Cuttings from a young pear tree branch showing the borings of

Scolytus rugulosus beneath fruit spurs. Each boring was the point of inoculation of bacterial blight. Blight cankers can be seen around each boring.

FIG. 3. Cuttings from a healthy young pear tree showing borings of *Scolytus rugulosus* at the base of the buds and spurs. Three of these cuttings had blight canker developing around the borings.

FIG. 4. Healthy young pear tree with glass tubes used in the experiment with *Scolytus rugulosus*, described in the text.

FIG. 5. Cuttings from one of the glass-enclosed branches shown in Fig. 4. A boring can be seen beneath each of the leaf buds. The blight was developing around two of these borings.

PLATE XXIV

FIG. 6. Young pear tree in advanced stage of bacterial blight after being inoculated with *B. amylovorus* by *Scolytus rugulosus*, This tree is the fifth in the row shown in Fig. 1. Photograph taken early in August, 1910.

FIG. 7. Blight canker near the base of the trunk of a young pear tree, (same tree as shown in Fig. 6, both photographs taken on the same day). Original inoculation of *B. amylovorus by Scolytus rugulosus* near the centre of the small canker where the puncture may be seen at *a*. From this canker the disease spread producing the larger canker which practically girdled the tree. Four of the beetles are shown in *b*, *c*, *d*, and *e*. In *b*, the end of the beetle is seen protruding from his boring ; a boring is also visible at *f*.

FIG. 8. Crotch of blighted pear tree shown in Fig. 6. Photograph taken end of April, 1911.

FIG. 9. Same as Fig. 8, with the bark turned back to show tunnellings of *Scolytus rugulosus* ; many larvae present.

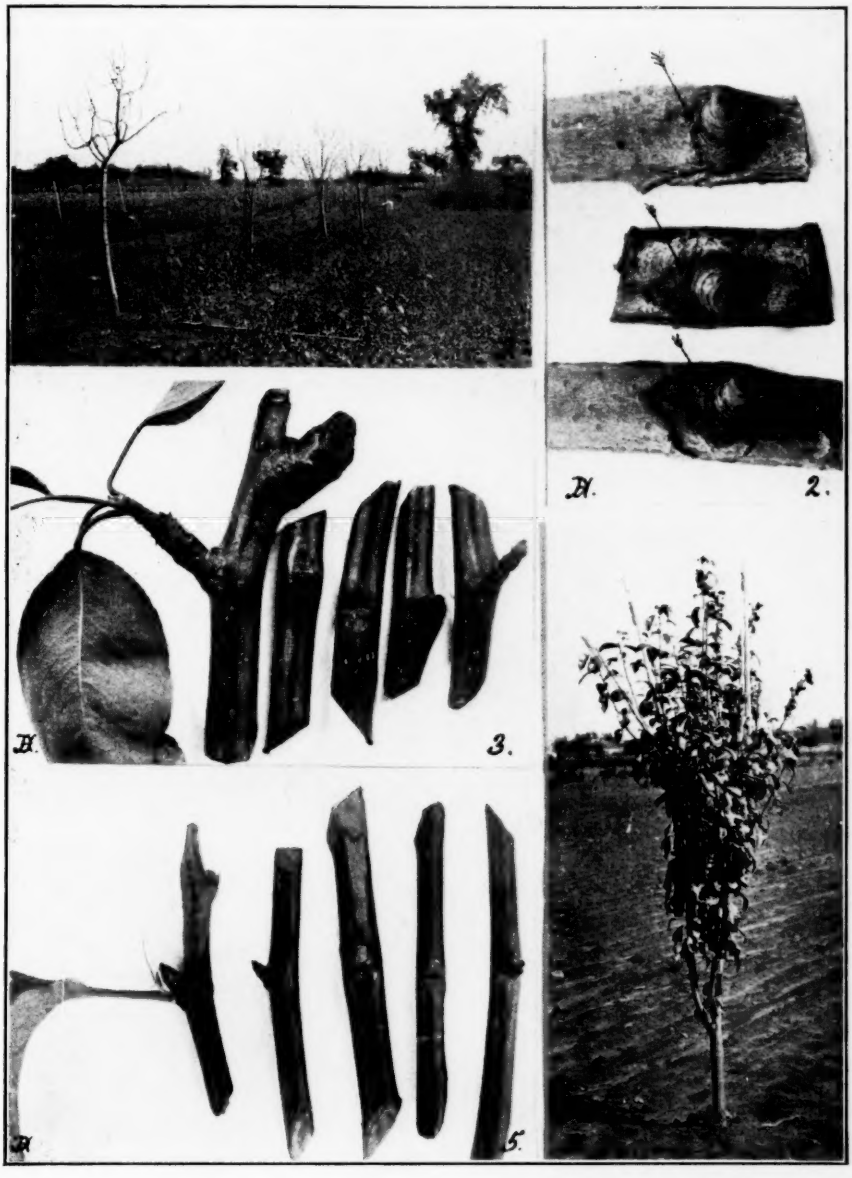

PLATE XXIII **Pear Blight spread by Scolytus rugulosus**

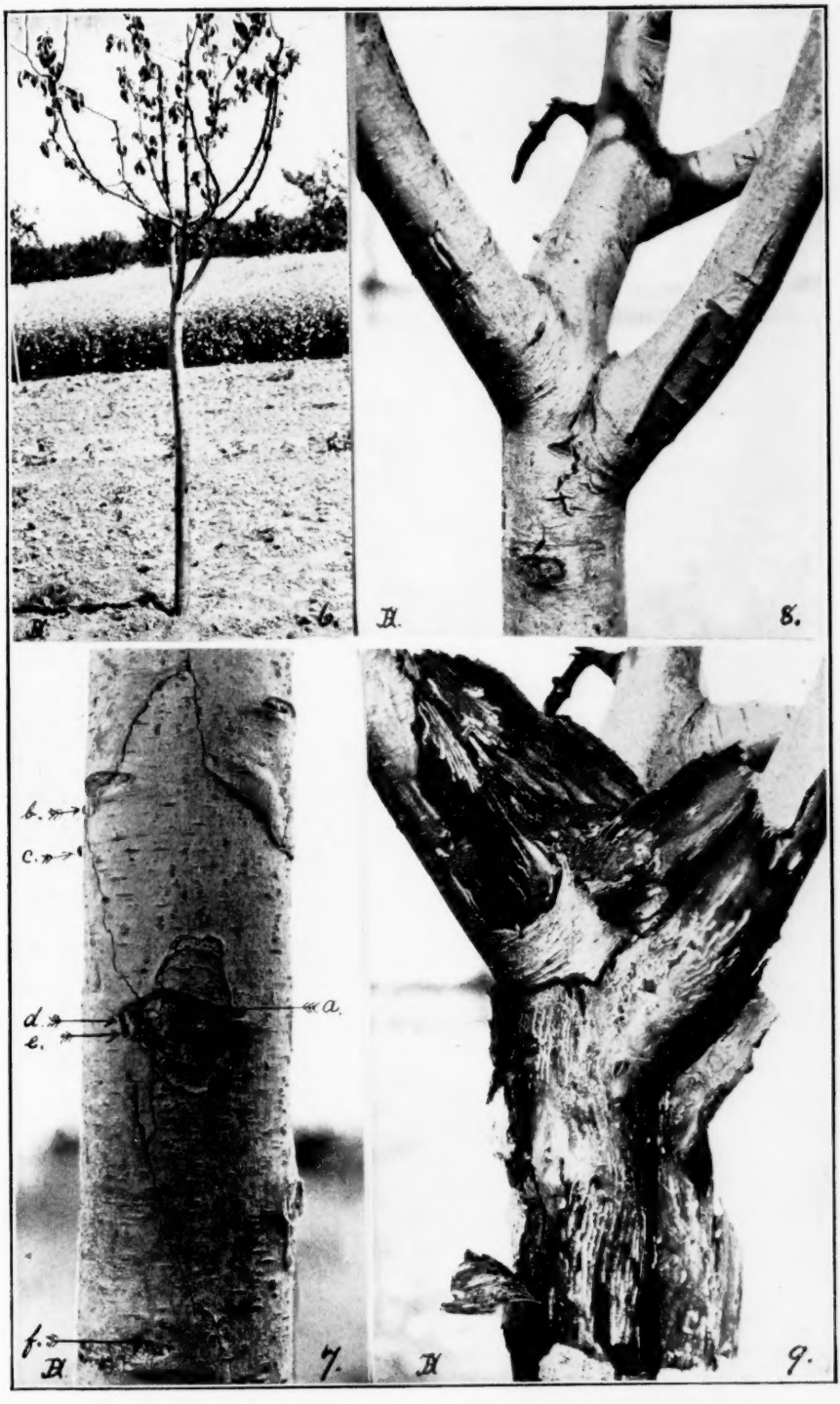

PLATE XXIV **Pear Blight spread by Scolytus rugulosus**

THE EFFECT OF THE CLUB ROOT DISEASE UPON THE ASH CONSTITUENTS OF THE CABBAGE ROOT[1]

HOWARD S. REED

During the course of a recent investigation of pathological conditions caused by the club root organism, *Plasmodiophora brassicae* Wor. the writer has had opportunity to compare the amount and ratio of the ash constituent of diseased and normal cabbage roots.

The large hypertrophied roots produced when cruciferous plants are attacked by this parasite are commonly well known to plant pathologists as well as to many growers. Cabbage plants affected by the parasite produce heads of inferior quality in favorable cases; in unfavorable cases no firm, merchantable heads whatever are produced. The common inference is that the nutrient substances acquired by or elaborated in the plant are appropriated by the roots and are expended in the formation of the enlarged organ.

Since the researches of Woronin[2] and of Nawaschin[3] have shown that the presence of *Pl. brassicae* in the cabbage root produces striking changes in the form and content of the cells resulting in hypertrophy, the question arises whether the parasite also causes changes in the chemical organization of the cabbage root. The diseased roots are found upon microscopical examination to contain a large amount of parenchyma tissue whose cells are in a living condition. These cells might be expected to contain greater or less amounts of extractives in addition to the proteins and other insoluble compounds. It is also possible that the atrophy of the cabbage head is due to an accumulation of the ash constituents in the tumor-like root.

Samples of cabbage roots (both healthy and diseased) were collected by the writer in August, 1910. The plants were all of the same age and taken from the same field. The roots were washed, scrubbed as free as possible from adhering soil, and dried in an oven. When dry, the roots were ground in a mill and stored in glass-stoppered jars until analyzed.[4]

The following table shows the result of the chemical analysis:

[1] Paper No. 11 from the Laboratory of Plant Pathology of the Virginia Agricultural Experiment Station, Blacksburg, Va.

[2] Woronin, M. Plasmodiophora Brassicae, Jahrb. wiss. Bot. **11**: 548. 1878.

[3] Nawaschin, S. Beobachtungen über den feineren Bau u. Umwandlungen von Plasmodiophora. Flora, **86**: 404. 1899.

[4] For the chemical analysis of these roots I am indebted to my colleague, Dr. W. B. Ellett, Chemist of the Virginia Agricultural Experiment Station.

TABLE I

Ash Content of Healthy and Diseased Cabbage Roots

	Healthy Roots	Diseased Roots
Ash	24.43%	19.20%
Sand and insoluble residue	74.31%	35.64%
CaO	2.02	6.20
MgO	1.30	2.28
P_2O_5	3.03	4.47
K_2O	6.76	30.33
SO_3	3.47	7.84
Na_2O	1.17	1.33
Fe_2O_3 and Al_2O_3	7.62	3.79
Mn_3O_4	trace	trace

From this table it would appear that the diseased roots were considerably richer in the first five ash constituents listed and it is regarded as especially significant that these are the mineral constituents usually regarded as being of primary importance in the nutrition of green plants. It may be pointed out that the ash content of the healthy roots was somewhat augmented by the large amount (74.31%) of sand and insoluble matter present in contrast to only about half that percentage (35.64%) in the diseased roots. It may be said in passing that the adhering soil was very difficult to remove from the finely branched fibrous roots and to the presence of this material is undoubtedly due the high percentage of sand and insoluble matter in the healthy cabbage roots. It seems more correct therefore to compute the analyses to the basis of the dry weight of the plant substance and to draw conclusions concerning the ratios of the ash constituents from the figures thus obtained, These figures appear in Table II.

TABLE II

Ash Constituents of Healthy and Diseased Cabbage Roots expressed as percentages of the Dry Weight of Plant Substance

	Healthy Roots	Diseased Roots
Sand and insoluble residue	18.15%	6.84%
CaO	0.49	1.19
MgO	0.31	0.44
P_2O_5	0.74	0.86
K_2O	1.65	5.82
SO_3	0.85	1.50
Na_2O	0.29	0.26
Fe_2O_3 and Al_2O_3	1.86	0.73
MnO	----	----

Calculated upon the basis of the dry weight of plant substance, the figures still show the same general relationships, *i. e.*, the diseased roots

were richer in their content of the first five ash constituents listed in tables I and II.

In order of magnitude the analysis of healthy roots agrees well with that reported by Patterson[1] although there are the natural differences in absolute amounts found in crops grown under different conditions of soil and climate.

The amount of potassium in both the healthy and the diseased roots is quite striking. Table 1 shows that 6.76% of the ash of the healthy roots was K_2O and that in the diseased roots the relatively large figure 30.33% of the total ash was K_2O. Based upon the dry weight as reported in Table II the percentages were 1.65% and 5.82% in the healthy and diseased roots respectively. This high percentage of potassium in the healthy roots was likewise reported by Patterson[2] but the particular point of present interest is the much increased amount of potassium found in the diseased roots.

Several considerations upon the structure and content of these club root cabbages aid in accounting for this increased amount of potassium. The heads and fleshy stalks which to some extent, at least, in the healthy cabbages serve as storage organs are lacking or poorly developed in those plants attacked by club root, consequently the fleshy club roots take up material which is more commonly found in the head. This argument however, applies equally to all. If it is primarily true of potassium there must be constituents in the cabbage club root for which potassium is especially characteristic. A consideration of the physiology and structure of the club root brings to light some facts which actually explain this large potassium content. There is, as might be predicted, an unusual development of cells and therefore increased content of protoplasmic material for which potassium is required to a greater or less extent.

A microscopical examination of sections of cabbage club roots shows the presence of a considerable quantity of starch, an accumulation which appears to be coordinated with the formation of the hypertrophied root tissue. Now the process of starch-building is one which appears to be largely conditional upon the presence of potassium as has been shown by numerous experiments[3].

It is also of interest to note in passing that the root of the flat turnip (a fleshy root of another member of the family Cruciferae) contains about the same percent of potassium as this cabbage club

[1]Patterson, H. J. Maryland Agr. Exp. Station, Bull. 133. 1909.

[2]Patterson, l. c.

[3]Vide Reed, H. S. The value of certain nutritive elements to the plant cell. Annals of Bot. 21: 501. 1907.

root. Van Slyke, Taylor and Andrews[1] report 5.45% K_2O for this plant (computed on basis of dry weight).

The relationships of potassium are also of interest in comparison with the ash content of tumors in the animal body, since it seems highly proper to regard the club root as a plant tumor caused by a specific organism. Clowes and Frisbie[2] reported that rapidly growing large tumors in mice contain a high percentage of potassium and a low percentage of calcium, whereas in old, slowly growing, necrotic tumors the relations are reversed.

The further examination of the analytical data reveals several other relationships which are considered to be of more or less importance in the economy of plant nutrition. These relationships are computed in the form of ratios for both the healthy and diseased roots and are presented in Table III as contrasted ratios.

TABLE III

Ratio of Certain Ash Constituents of Healthy and Diseased Cabbage Roots

Healthy Roots	Diseased Roots
$CaO : MgO :: 1.00 : .63$	$CaO : MgO :: 1.00 : .37$
$K_2O : Na_2O :: 1.00 : .17$	$K_2O : Na_2O :: 1.00 : .045$
$P_2O_5 : MgO :: 1.00 : .42$	$P_2O_5 : MgO :: 1.00 : .51$

The first of these ratios shows that in healthy cabbage roots the proportion of calcium to magnesium is less than in the diseased roots, although in both cases calcium preponderates over magnesium.

The preponderance of magnesium over calcium in the culture medium is usually detrimental to the growth of chlorophyll-containing plants as has been shown by numerous experimenters and Loew[3] has cited cases in which abnormal or supposedly diseased plants contained relatively less lime than magnesium. This does not, however, appear to be the case in cabbage club root since there is proportionally much more calcium than magnesium in the diseased roots. Also there is absolutely more calcium in the diseased roots.

The ratio of potassium to sodium in healthy and diseased roots is another point of interest shown by the figures in Table III. The

[1] Tabulated analyses showing amounts of plant food constituents in fruits, vegetables, etc. N. Y. Agr. Exp. Station, Bull. 265. 1905.

[2] Clowes and Frisbie. On the relationship between the rate of growth, age, and potassium and calcium content of mouse tumors (adeno-carcinoma) Amer. Jour. Physiol, 14 : 173. 1905.

[3] Loew, O. The Physiological Rôle of Mineral Nutrients. U. S. Dept. Agr., Bur. Pl. Ind. Bull. 45 : 39. 1903.

ratio for the healthy roots is about four times greater than for the diseased, because of the increased amount of potassium in the latter, whereas the percentage of sodium in the two is almost identical.

The ratio of magnesium to phosphorus in the club root cabbage does not materially differ from that found in the normal although the absolute amount present in the diseased roots was higher than that in the healthy. The differences, however, are not great enough to throw much light upon the question raised by Loew as to whether magnesium serves as a carrier for phosphoric acid in the organism.

SUMMARY

1. The ash analysis of healthy and diseased cabbage roots reveals appreciable variations in the amounts of certain constituents while others vary but slightly.

2. In the diseased roots there was an appreciable increase in the amounts of calcium, magnesium, phosphoric acid, potassium, and sulphuric acid, *i. e.* an increase in the amounts of "essential" elements.

3. The greatest increase of any single constituent was in the case of potassium. The increase of potassium appears to be coupled with an increase of protoplasmic substance and an accumulation of starch.

4. The proportion of calcium to magnesium is greater in the diseased roots. The same is also true of the proportion of potassium to sodium, but there is no material difference in the proportion of magnesium to phosphorus.

5. The differences in the amounts and proportion of ash constituents appear sufficiently well marked to indicate a more or less definite correlation in the metabolism both of healthy and of diseased plants.

A VARIETY OF CLADOSPORIUM HERBARUM ON CITRUS AURANTIUM IN FLORIDA

H. S. FAWCETT AND O. F. BURGER

In investigating a disease known as Scaly Bark of citrus trees in Florida a fungus similar to, yet differing from, *Cladosporium herbarum*, was isolated repeatedly from diseased spots, and when inoculated into sweet orange trees (*Citrus aurantium*) was found to produce the early stages of the disease on small branches. An examination of the diseased spots at different seasons of the year showed that there were present a number of spore-forms: the one-celled spherical Hormodendron form, the two-celled Cladosporium form, and the clump or packet Coniothecium form, as well as microsclerotia. All these forms were afterwards produced in pure cultures and shown to be forms of one species of fungus. The two first mentioned forms of spore, together with the formation of microsclerotia, have been observed by Bancroft[1] in *Cladosporium herbarum* which he has shown to be parasitic on various plants in England. On initial spots on Citrus in Florida the spores and hyphae were usually hyaline to only slightly colored; but, as the spots became older, there was a tendency for the hyphae and spores to become straw-colored to smoky. During warm weather there was apparently a tendency towards the production of a greater number of the one-celled spherical Hormodendron spores, while during the cooler weather there were more of the oval one-celled and the two-celled Cladosporium spores formed. During the fall and winter, which is a dry season in Florida, the Coniothecium or clump form of spore was produced, and also a kind of microsclerotium.

The spores on the spots in numerous measurements were found to vary much. The one-celled spherical Hormodendron spores measured 3-6 microns in diameter. The Cladosporium-like spores measured when one-celled 6-9 by 3-6, and the two-celled spores measured 8-12 by 4-6. The small hyaline hyphae were 1-3 microns, and the older colored hyphae 2-6 microns in width, with segments 6-9 microns long. In cultures the most common form of spore is the one-celled.

Parallel cultures of this fungus with *Cladosporium herbarum* Lk. (obtained from Dr. Westerdyk of the Bureau for the distribution of pure cultures of fungi, Amsterdam, Holland) on a large number of different media, showed distinct differences in growth and spore formation. These differences were, however, not considered sufficient to warrant a new specific name in the present condition of the "species" *C. herbarum*, Lk., so that it was thought best to designate it *C.*

[1]Annals of Botany, **24**: 359-372. 1910.

GROWTH IN STANDARD PEPTONIZED AGAR.[1]

Percentage of Normal Acid or Alkali	Cladosporium herbarum var. citricolum of Scaly Bark.	Cladosporium herbarum from Dr. Westerdyk.
1.5 acid	(24 hours) Spores germinating, hyphae 4-6 times longer than spore, branching early.	Spores germinating, hyphae 10–20 times the length of spore; unbranched as yet.
1.5 acid	(4 days) Colonies smaller, more dense, lighter with more even margins. Hyphae more hyaline, more branched, not constricted at septa. Spherical spores, 3-5 microns diameter; oval spores, 5-8 by 4; hyphae 3-5 microns in diameter.	Colonies larger, more open, with more irregular margins; growth more on surface of media Hyphae more colored (septa more prominent) straighter, less branched. Spherical spores 5-6 microns; oval 6-12 by 5-6 microns diam. Spore heads more open. Spores not so numerous.
3 acid	(4 days) Growth about same as for C. herbarum. (13 days) Colonies thinner and lighter on edge, dark in center.	Growth about same but lighter in color than same fungus in 1.5 acid (13 days). Colonies seal-brown. Spores more abundant than same fungus in 1.5 acid.
5 acid	(4 days) Growth much as in 3 per cent. acid. Abundant spores.	Growth about same amount as C. herbarum var. citricolum, but spore heads more open.
8 acid	(4 days) No growth. (23 days) Slight delicate growth.	Good growth, spore production abundant.
10 acid	(4 days) No growth. (13 days) No growth.	(4 days). Fair growth on surface of medium. (13 days) Dark crust forming on surface of medium.
12 acid	(4 days) No growth. (13 days) No growth.	(4 days) No growth. (13 days) No growth.
Neutral	(4 days) Colonies light gray. (13 days) Colonies lighter than other fungus.	(4 days) Good growth, about same as other fungus. Spore production fairly abundant. (13 days) Colonies darker than C. herbarum var. citricolum.
1.5 alkali	(4 days) No growth. (13 days) Slight growth, no spores.	(4 days) Very abundant growth, whitish, no spores. (13 days) Few spores formed.
3 alkali	(4 days) No growth (13 days) No growth.	(4 days) White growth, less abundant than in 1.5 alkali. (13 days) Few spores, but less than in 1.5 alkali.

[1]The cultures were made by Mr. O. F. Burger who also assisted in taking notes on the same.

herbarum var. *citricolum*. In general, on all of the various media, the average diameters of the spores and hyphae of *C. herbarum* var. *citricolum* were smaller than those of *C. herbarum* from Amsterdam. The spores of the former were usually more strictly Hormodendron-

like, and, when the fungi were growing under favorable conditions, many times more abundant. The differences of growth in standard peptonized agar at various percentages of normal acid and alkali are here given in a tabular form. The acid used was normal hydrochloric, and the alkali, normal sodium hydroxide. The temperature varied between 25 and 30 degrees C.

A more detailed description of this fungus and its relation to Scaly Bark of Citrus is being published as Bulletin 106 of the Florida Agricultural Experiment Station.

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The Black Rot Disease of the Grape. Reddick, Donald. Cornell University Agricultural Experiment Station, Bulletin 293, pp. 65, plates 5, figs. 15. March 1911.

In this paper, which was presented as a major thesis at Cornell University in partial fulfillment of the requirements for the degree of Doctor of Philosophy, Reddick gives an account of his investigations of the Black Rot disease of the grape. The work is introduced by a short historical sketch of the inception of the grape industry in America. and a brief account of the disease and its influence on grape-growing. The author then takes up the etiology of the fungus, (*Guiguardia bidwellii* (Ell.) V. & R.), causing the disease. This is followed by the life history of the organism, beginning with the perithecium, its mode of development and dehiscence and the relation of the dehisence to the meteorological conditions. He does not find paraphyses in the perithecia, disagreeing in this with some of the earlier writers. The pycnidia were found to develop very rapidly after the lesion caused by the fungus was first evident, sometimes reaching complete maturity in forty-two hours. These organs may be found on any of the new growths of the host, and the fungus may possibly winter over in this form on the tendrils and canes. Serious infections in the early spring were caused by the pycnospores originating on the old mummies and parts of the growth of the previous season. The author was unable to find the hyaline appendage of the pycnospores reported by Shear and occasionally observed since by the reviewer. Reddick seems inclined to consider the spermatia as vestigial male sexual elements, basing his conclusions mainly on the fact that they are frequently borne at the same time as the sclerotia like organs, which he has named pycnosclerotia and which he regards as incipient perithecia. The author was able to find what he considered conidia but once and then on an old mummied berry.

Reddick reports that pycnospores develop in enormous quantities up to the first of August, but after that on berries showing new spots spermagonia and pycnosclerotia develop. Fertile pycnidia are not usually present. He does not seem to consider that the meteorological conditions may influence the kind of fruiting bodies formed. The reviewer has observed the formation of sterile pycnidia and spermogonia very abundantly as early in the season as June 25th, when the fruiting bodies were formed during a period of low humidity and high temperature, and has also found pycnidia very abundant in the latter part of August and in September when there had been frequent rains

and generally wet weather during these months. It seems, to the reviewer, that the humidity and temperature of the air play a more important part in the determination of the kind of fruiting bodies formed than might be inferred from the author's writings.

It is difficult to understand why the cultural study of the fungus and the thousands of inoculations made with both ascospores and pyncospores yielded such indifferent results. Only the one fruiting stage, (pycnidia), of the four he figures was produced in cultures and he reports positive results from none of the inoculations. From the description of the inoculation experiments it would seem that the author had taken all possible precautions to insure successful infection.

The bulletin is illustrated with numerous halftone figures as well as with four plates of photo-micrographs and one of drawings. The poor paper upon which the halftones are reproduced robs the apparently excellent photographs of much of their value. An exceptionally good bibliography of fourteen and one-half pages is part of the publication. The work as a whole is a very valuable contribution to our knowledge of this disease; while nothing strikingly new is reported, yet the many careful observations and experiments, together with the close attention to detail in the investigation, extending over two years give it a high rank in the voluminous literature of the subject. It seems to the reviewer to be the best and most complete work on the subject.

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ANNOUNCEMENT

The American Phytopathological Society will hold its third annual meeting at Washington, D. C., December 27th to 30th, in affiliation with the American Association for the Advancement of Science. Joint sessions with Section G of the American Association for the Advancement of Science, Botanical Society of America, and Bacteriological Society are being arranged. The exact time of the sessions, call for papers, hotel headquarters and other details will be given in a circular letter to be issued in November. In the meantime we trust that as many members as possible will begin to make plans to attend the meeting and prepare papers to be presented. It is expected that the Washington meeting will be of unusual interest and importance to plant pathologists and botanists in general.

C. L. SHEAR,
Secretary-Treasurer